The Impact of Regulatory Control on Monitoring of Pregnant Hospital Staff In Diagnostic Radiology

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Abstract

In 1990, the International Commission on Radiological Protection recommended the introduction of a supplementary dose limit for pregnant staff so that the foetus was adequately protected. This dose limit was framed in terms of an abdomen surface dose of 2 mSv for the duration of the pregnancy, once it had been declared. The philosophical basis underlying this supplementary dose limit was the desire to treat the foetus as a member of the public in respect of the occupational exposure of the mother. In the Basic Safety Standards, the International Atomic Energy Agency endorsed the need to limit the foetal dose, but in this document the dose limit refers to the foetus. The introduction of dose limits for foetal exposure to radiation has significant implications for hospitals as many workers are women of child bearing age. The practical implications of this dose limit will be discussed as well as suggested monitoring arrangements.

1. Introduction

In report 60, the International Commission on Radiological Protection (1) recommended the introduction of a supplementary dose limit to protect the foetus of pregnant workers. The recommended dose limit was 2 mSv to the surface of the abdomen for the remainder of the pregnancy, once pregnancy has been declared. The intention of this supplementary dose limit is to treat the foetus as a member of the public and to limit the dose accordingly.

In the Basic Safety Standards (2), the International Atomic Energy Agency endorsed the need to limit the foetal dose, but in this document the dose limit refers to the foetus. The introduction of dose limits for foetal exposure to radiation has significant implications for hospitals as many workers are women of child bearing age. The practical implications of this dose limit will be discussed as well as suggested monitoring arrangements.

2. Exposures In Diagnostic Radiology

In general, radiation dose levels received by members of staff who are occupationally exposed are relatively low, typically being in the range 0-3 mSv (4) in diagnostic radiology.
These relatively low levels of radiation dose reflect good radiation protection practices. However, there are a group of procedures in interventional radiology in which it is possible to approach the supplementary dose limits for pregnant staff for a realistic number of patient studies. Thus there is a potential monitoring problem for radiologists, radiographers, nurses and clinical staff associated with high dose interventional procedures.

3. Materials and Methods

Scattered radiation conditions typical of those encountered in fluoroscopy were simulated for primary x-ray beams generated at 70, 90 and 110 kV. In abdomen phantom (3M, Minnesota, USA) was placed on a patient couch and irradiated with a primary beam. The field size of the primary beam was 20 x 20 cm measured on the entrance surface. A focus skin distance (FSD) of 1m was used for the simulation of an overcouch x-ray tube/undercouch image intensifier geometry, whilst an FSD of 0.45 m was used for an undercouch x-ray tube/overcouch image intensifier geometry.

A staff member standing at the couch side was represented by a Rando anthropomorphic phantom (Alderson Research Laboratories, Stamford, USA). Seventeen lithium fluoride thermoluminescent dosemeter chips were used to measure uterus dose. A further 20 dosemeters were used for background and calibration purposes. The equivalent dose to the uterus was determined from the mean of the dosemeter readings, after applying an energy dependent correction factor and subtracting the background reading.

Film badges supplied by the Regional Medical Physics Department's Approved Dosimetry Laboratory were attached to the Rando phantom at waist level. For each irradiation condition two dosemeters (left and right) were used. The waist level film badge dosemeter reading was the mean of the two individual results.

Extended fluoroscopy times were used to irradiate the anthropomorphic phantom loaded with thermoluminescent dosemeters. This ensured that the dosemeter readings were above background.

Uterus dose and film badge dosemeter readings when a lead apron is worn were estimated from the unshielded results. A transmission factor for the attenuation of scattered radiation through lead was applied. The transmission factor was deduced from previously published data (5).

Direct irradiation of staff in diagnostic radiology was also simulated. The Rando phantom leaded with lithium fluoride dosemeters was irradiated in a primary beam. Three tube potentials were investigated (70, 90, 110 kV). Protective aprons, either 0.25 mm or 0.33 mm lead equivalent were used to shield the phantom. The unshielded case was also simulated.

4. Results

Table 1 gives the ratio of uterus equivalent dose to waist level film badge dosemeter reading at three tube potentials for scattered radiation from both an overcouch x-ray tube/undercouch image intensifier and an overcouch image intensifier/undercouch x-ray tube geometry. Table 2 summarises the results for direct irradiation in diagnostic radiology.

5. Discussion

It may be deduced from table 1 that the ratio of uterus equivalent dose to film badge dosemeter reading are dependent on irradiation conditions. However, in all instances studied this ratio is 0.3 or lower. This implies that the uterus dose is less than or equal to 30% of the dose monitored by the film badge. This accumulating a dose of 2 mSv on a film badge dosemeter, would equate to a dose of 0.6 mSv at most to the foetus. The application of a 2 mSv
abdomen dose limit will therefore adequately protect the foetus from scattered radiation in diagnostic radiology.

For primary radiation the ratio of uterus dose to film badge dosemeter reading lie in the range 0.2 - 0.55. This implies that for some irradiation conditions, the foetus could receive a dose greater than 1 mSv, for an accumulated dosemeter reading of 2mSv. The direct irradiation of staff in diagnostic radiology should only occur as a result of an accidental exposure. Fortunately, this is relatively unlikely to occur.

In interventional radiology, it is possible to exceed the abdomen dose limit for a relatively low number of procedures. Extrapolating from previous work (7), indicates that a cardiologist need only perform 22 cardiac catheterisations to exceed the limit, and a nurse only 66.

Suggested Monitoring Scheme
1) Staff working in diagnostic radiology, particularly interventional radiology, should a dosemeter at waist level. This dosemeter overestimates foetal dose, so ensuring that the accumulated dosemeter reading does not exceed 2 mSv will ensure that the foetal dose does not exceed 7 mSv.
2) Use of electronic dosemeters to monitor stuff in interventional radiology is recommended.

Table 1

Ratio of the Uterus Equivalent Dose to Waist Level Dosemeter Reading (film Badge) at three Tube Potentials (70,90,110 kv) for scattered radiation from an Undercouch X-ray Tube/ Overcouch Image Intensifier and Overcouch X-ray tube/Undercouch Image Intensifier Equipment.

<table>
<thead>
<tr>
<th>Tube Potential</th>
<th>Lead Apron Thickness (mm lead)</th>
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<tbody>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Overcouch x-ray tube</td>
<td>70</td>
</tr>
<tr>
<td></td>
<td>90</td>
</tr>
<tr>
<td></td>
<td>110</td>
</tr>
<tr>
<td>Undercouch x-ray tube</td>
<td>70</td>
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<tr>
<td></td>
<td>90</td>
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<tr>
<td></td>
<td>110</td>
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</tbody>
</table>
Table 2

Ratio of Uterus Equivalent Dose to Waist Level Dosemeter Reading (film badge) for Primary Irradiation

<table>
<thead>
<tr>
<th>Tube Potential</th>
<th>0</th>
<th>0.25</th>
<th>0.33</th>
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<tr>
<td>70</td>
<td>0.25</td>
<td>0.50</td>
<td>0.55</td>
</tr>
<tr>
<td>90</td>
<td>0.21</td>
<td>0.46</td>
<td>0.53</td>
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<tr>
<td>110</td>
<td>0.20</td>
<td>0.43</td>
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Acknowledgements

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References